Residential Window Efficiency

2013 California Building Energy Efficiency Standards

May 2011

CONTENTS

1. Purpose ... 3
2. Overview ... 4
3. Methodology ... 12
3.1 Context ... 12
3.1.1 2008 Title 24 ... 12
3.1.2 Relevant National Efficiency Standards ... 12
3.2 Data Collection ... 13
3.3 Energy Savings and Cost-effectiveness ... 14
3.3.1 Criteria for evaluating cost-effective solution ... 14
3.3.2 Building Prototypes and Simulation Parameters ... 16
4. Analysis and Results ... 18
4.1 Relevant National Standards ... 18
4.1.1 Energy Star ... 19
4.1.2 The International Energy Conservation Code (IECC) ... 19
4.1.3 Federal Tax Credits ... 20
4.2 Data Collection ... 21
4.2.1 Surveys and Interviews ... 21
4.2.2 Retail Site Visits ... 23
4.2.3 Overall Findings ... 24
4.3 Energy Simulation Analysis ... 25
4.3.1 Analysis Setup ... 25
4.3.2 Results ... 26
4.4 Conclusions and Recommendations – New Construction ... 27
4.4.1 Savings and Cost-effectiveness: Single-Family ... 27
4.4.2 Savings and Cost-effectiveness: Multi-Family ... 29
4.5 Conclusions and Recommendations – Existing Buildings ... 30
5. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices ... 31
5.1 Package D ... 31
5.2 Package C ... 31
5.3 Package E ... 32
6. Bibliography and Other Research ... 33
6.1 Documents and Resources ... 33
7. Appendices ... 34
7.1 Survey Instruments ... 34
7.1.1 Manufacturer and Dealer Market Survey: ... 34
7.2 Stakeholder Outreach ... 34
7.2.1 CASE Residential Envelope Stakeholder meetings ... 34

7.2.2 Conference Presentations....35
7.3 Data Collection....35
7.3.1 Retail Sites....35
7.3.2 Survey Contacts....35

FIGURES

Figure 1: Energy Benefits, Single-Family Prototype D.... 5
Figure 2: Energy Benefits, Multi-Family Prototype E.... 6
Figure 3: Summary of Cost-effectiveness, Single-Family Prototype D.... 8
Figure 4: Summary of Cost-effectiveness, Multi-Family Prototype E.... 9
Figure 5: Summary Description of Simulated Prototype Buildings.... 16
Figure 6: Summary of Evaluated Window Performance Packages.... 16
Figure 7: Summary of Relevant National Fenestration Performance Standards.... 18
Figure 8: ENERGY STAR Climate Zone Map.... 19
Figure 9: IECC Climate Zone Map and Minimum Window Performance Requirements (2012).... 20
Figure 10: Survey Respondents’ Reported California Sales Volumes by Performance Level.... 21
Figure 11: Survey Respondents’ Reported California Sales Volumes by Residential Market Sector . 22
Figure 12: Building Department Survey, Frequency of Prescriptive Compliance.... 22
Figure 13: Retail Site Visits, Product Histogram: U-factor.... 23
Figure 14: Retail Site Visits, Product Histogram: SHGC.... 24
Figure 15: Primary “Straw Proposals” Evaluated.... 26
Figure 16: Summary Comparison of Straw Proposal Simulation Statewide Results.... 27
Figure 17: Standard and Proposed Fenestration Cases.... 27
Figure 18: Comparison of Proposed and Standard Simulation Results, Single Family Prototype D... 28
Figure 19: Comparison of Proposed and Standard Simulation Results, Multi-Family Prototype E 29
Figure 20: Proposed Revisions to Standards Section 151, Table 151-C.... 31
Figure 21: Proposed Revisions to Standards Section 151, Table 151-B (TBD).... 32

1. Purpose

This Codes and Standards Enhancement (CASE) report regards potential changes to the 2008 California Building Energy Efficiency Standards for adoption into the 2013 Standards. It proposes revisions to the prescriptive U- factor and Solar Heat Gain Coefficient (SHGC) requirements for residential fenestration and summarizes the research supporting these revisions.

2. Overview

a. Measure Title	Residential Window Efficiency
b. Description	This CASE report proposes revisions to the fenestration requirements in the residential Prescriptive Packages C, D, and E. Code language revisions detailed in Sections 5.1, 5.2, and 5.3 are briefly summarized below: <u>Package D</u>: Max U-factor = 0.32, all climate zones Max Solar Heat Gain Coefficient (SHGC) = 0.25, all climate zones except 1, 3, and 5, which have No Requirement (NR) <u>Package C</u>: TBD (see Section 5.2) <u>Package E</u>: Recommend removing this prescriptive package from the Standards.
c. Type of Change	This CASE report proposes modifications to low-rise residential prescriptive requirements, which must be met when using the prescriptive compliance method. When using performance compliance, prescriptive requirements define the standard design (which sets the energy budget) and are not mandatory. Adoption of this proposal would result in changes to Standards Tables 151-B, C, and E (Packages C, D, and E). Changes to the Residential Alternative Calculation Manual (ACM) would be necessary only to the extent that the standard design would change to reflect the proposed revised prescriptive requirements.
d. Energy Benefits	Relative to current code-compliant residential construction, that built to the proposed prescriptive revisions would yield positive annual TDV savings in all climate zones, kwh savings in all climate zones, and therm savings in four climate zones. Cooling TDV and energy savings would lower peak electrical demand due to reduced air conditioning loads in all but one climate zone. This study shows that updating window prescriptive requirements as recommended is highly cost effective and results in statewide TDV savings on the order of 14% and 9% for the single-family and multi-family building prototypes, respectively. Calculated savings by evaluated prototype building and climate zone are summarized in Figure 1 and Figure 2, below.

Climate Zone	Electricity Savings (kwh/yr)	Demand Savings (kw)	Natural Gas Savings (Therms/yr)	TDV Electricity Savings (mTDV/yr)	TDV Gas Savings (mTDV/yr)
01	45	-	36.5	-	7.0
02	150	0.4	(20.8)	15.9	(3.9)
03	40	0.0	19.2	1.8	3.9
04	301	0.7	(22.1)	25.3	(4.3)
05	90	(0.0)	80.2	(1.0)	15.6
06	316	0.7	(20.0)	22.4	(4.0)
07	224	0.5	(13.5)	17.0	(2.6)
08	461	0.8	(14.6)	27.0	(2.9)
09	562	0.9	(15.9)	34.9	(3.2)
10	601	1.0	(17.6)	37.6	(3.4)
11	796	1.3	(14.6)	51.1	(2.7)
12	577	0.9	(11.9)	36.1	(2.1)
13	846	1.4	(7.8)	51.7	(1.5)
14	754	1.0	(25.9)	41.3	(5.0)
15	957	0.8	0.5	38.0	0.1
16	643	1.6	(93.2)	55.4	(18.0)

Figure 1: Energy Benefits, Single-Family Prototype D

Climate Zone	Electricity Savings (kwh/yr)	Demand Savings (kw)	Natural Gas Savings (Therms/yr)	TDV Electricity Savings (mTDV/yr)	TDV Gas Savings (mTDV/yr)
01	82	-	64.0	-	12.5
02	483	1.1	(21.6)	41.3	(4.0)
03	68	0.1	32.0	4.2	6.6
04	789	1.5	(21.6)	54.7	(4.2)
05	14	(0.3)	103.0	(11.9)	20.6
06	897	1.3	(9.7)	48.1	(2.0)
07	721	1.1	-	40.7	(0.1)
08	1,033	1.3	(6.3)	51.6	(1.2)
09	1,176	1.6	(10.4)	65.2	(2.2)
10	1,237	1.6	(13.2)	66.5	(2.6)
11	1,665	1.9	(8.4)	80.1	(1.5)
12	1,230	1.7	(4.2)	67.7	(0.6)
13	1,693	1.8	0.7	77.4	0.1
14	1,577	1.7	(30.6)	75.1	(5.9)
15	1,869	1.3	-	67.2	-
16	1,631	3.2	(131.5)	115.9	(25.7)

Figure 2: Energy Benefits, Multi-Family Prototype E

e. Non-Energy Benefits	Non-energy benefits from increased window performance can include increased occupant comfort.

f. Environmental Impact

The proposed revisions promote fenestration of the same range of materials and general manufacturing and construction practices currently typical in the market. As such, their implementation would result in no known adverse environmental impacts, including any related to contaminants, water consumption, or water quality.

g. Technology Measures	Window products meeting the proposed prescriptive performance values are readily available in products from a large majority of window manufacturers and from common retail outlets. The proposed performance levels are regularly met by currently installed products in both new California homes and in the replacement window market. Vinyl, wood, fiberglass or other non- metal frame windows with low-E glass can meet the proposed prescriptive requirements. The proposed revisions will not directly affect the maintenance, longevity, or useful life of residential fenestration products available in California.
h. Performance Verification of the Proposed Measure	The currently required National Fenestration Rating Council (NFRC) labels can continue to serve as an effective performance verification tool. Builders and enforcement personnel are already trained to rely on the NFRC label to verify the U-factor and SHGC values of residential fenestration products.

i. Cost Effectiveness

The proposed prescriptive requirement revisions are calculated to be cost effective in all climate zones for the residential new construction prototype buildings evaluated. Figure 3 and Figure 4 below summarize this study's cost-effectiveness analysis for the single and multi-family prototype buildings, respectively. Additional information is presented in Sections 3 and 4 of this report.

a	b	c		d		e		f	g	
Measure: Fenestration Prescriptive Performance Requirements, by Climate Zone	Measure Life (Years)	Additional Costs[1]– Current Measure Costs (Relative to Basecase) ($)		Additional Cost[2]– Post-Adoption Measure Costs (Relative to Basecase) ($)		PV of Additional[3] Maintenance Costs (Savings, Relative to Basecase) (PV$)		PV of[4] Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
		Per Unit (sf of window area)	Per Proto Building	Per Unit (sf of window area)	Per Proto Building	Per Unit	Per Proto Building		(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
1	30	$0.71	$383	$0.36	$192	$0	$0	$1,216	($833)	($1,024)
2	30	$0.71	$383	$0.36	$192	$0	$0	$2,090	($1,707)	($1,899)
3	30	$0.71	$383	$0.36	$192	$0	$0	$982	($599)	($790)
4	30	$0.71	$383	$0.36	$192	$0	$0	$3,624	($3,241)	($3,432)
5	30	$0.71	$383	$0.36	$192	$0	$0	$2,525	($2,142)	($2,334)
6	30	$0.71	$383	$0.36	$192	$0	$0	$3,184	($2,801)	($2,993)
7	30	$0.71	$383	$0.36	$192	$0	$0	$2,488	($2,105)	($2,296)
8	30	$0.71	$383	$0.36	$192	$0	$0	$4,162	($3,779)	($3,970)
9	30	$0.71	$383	$0.36	$192	$0	$0	$5,494	($5,111)	($5,303)
10	30	$0.71	$383	$0.36	$192	$0	$0	$5,920	($5,537)	($5,728)
11	30	$0.71	$383	$0.36	$192	$0	$0	$8,380	($7,997)	($8,188)
12	30	$0.71	$383	$0.36	$192	$0	$0	$5,887	($5,504)	($5,696)
13	30	$0.71	$383	$0.36	$192	$0	$0	$8,698	($8,315)	($8,506)
14	30	$0.71	$383	$0.36	$192	$0	$0	$6,294	($5,911)	($6,102)
15	30	$0.71	$383	$0.36	$192	$0	$0	$6,607	($6,224)	($6,416)
16	30	$0.71	$383	$0.36	$192	$0	$0	$6,486	($6,103)	($6,294)

Figure 3: Summary of Cost-effectiveness, Single-Family Prototype D

a	b	c		d		e		f	g	
Measure: Fenestration Prescriptive Performance Requirements, by Climate Zone	Measure Life (Years)	Additional Costs[1]– Current Measure Costs (Relative to Basecase) ($)		Additional Cost[2]– Post-Adoption Measure Costs (Relative to Basecase) ($)		PV of Additional[3] Maintenance Costs (Savings, Relative to Basecase) (PV$)		PV of[4] Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
		Per Unit (sf of window area)	Per Proto Building	Per Unit (sf of window area)	Per Proto Building	Per Unit	Per Proto Building		(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
1	30	$0.71	$741	$0.36	$371	$0	$0	$2,170	($1,428)	($1,799)
2	30	$0.71	$741	$0.36	$371	$0	$0	$6,461	($5,720)	($6,090)
3	30	$0.71	$741	$0.36	$371	$0	$0	$1,880	($1,139)	($1,510)
4	30	$0.71	$741	$0.36	$371	$0	$0	$8,751	($8,010)	($8,381)
5	30	$0.71	$741	$0.36	$371	$0	$0	$1,507	($765)	($1,136)
6	30	$0.71	$741	$0.36	$371	$0	$0	$7,980	($7,238)	($7,609)
7	30	$0.71	$741	$0.36	$371	$0	$0	$7,039	($6,298)	($6,669)
8	30	$0.71	$741	$0.36	$371	$0	$0	$8,739	($7,998)	($8,368)
9	30	$0.71	$741	$0.36	$371	$0	$0	$10,921	($10,180)	($10,550)
10	30	$0.71	$741	$0.36	$371	$0	$0	$11,065	($10,324)	($10,695)
11	30	$0.71	$741	$0.36	$371	$0	$0	$13,609	($12,868)	($13,238)
12	30	$0.71	$741	$0.36	$371	$0	$0	$11,608	($10,867)	($11,237)
13	30	$0.71	$741	$0.36	$371	$0	$0	$13,428	($12,687)	($13,057)
14	30	$0.71	$741	$0.36	$371	$0	$0	$11,982	($11,240)	($11,611)
15	30	$0.71	$741	$0.36	$371	$0	$0	$11,644	($10,903)	($11,273)
16	30	$0.71	$741	$0.36	$371	$0	$0	$15,622	($14,881)	($15,251)

Figure 4: Summary of Cost-effectiveness, Multi-Family Prototype E

Incremental costs to meet the proposed prescriptive requirements vary somewhat by window type (slider, fixed, sliding glass door, etc.), but across types they range from low to zero. The same incremental costs were used in analysis of both single-family and multi-family prototypes and are listed in Column c of Figure 3 and
Figure 4, above. It is worth noting that as standard practice many California builders already install, and retail outlets already stock, fenestration products meeting the proposed requirements. The authors of this report estimate incremental costs after adoption in 2013 will, for the large majority of installed windows, will be at or near zero as manufacturers tailor performance of their California baseline products to even more fully align with the proposed prescriptive requirements. Conservatively, post-adoption incremental costs listed in Column d are estimated to be half of the current ones. The proposed requirements entail no known additional maintenance costs, as reflected in Column e of both above figures.

This section, as well as most of this report, regards new construction. Due to the varying vintages of existing buildings and the varying nature of their window types, quantifying expected savings for fenestration retrofits of a ‘typical’ existing prototype single or multi-family building is less feasible.

However, following the reasonable assumption that existing California buildings, including their windows, are less energy efficient than new construction, retrofit / replacement windows would therefore result in a greater savings for the same incremental cost. Thus the proposed revisions are deemed cost-effective for the retrofit/replacement market as well.

j. Analysis Tools	The CALRES energy software tool, revised for the 2013 Standards, was used to quantify energy savings and peak reduction for the proposed revisions. No additional software enhancements are required to support this proposal.
k. Relationship to Other Measures	U-factor and SHGC values in the 2008 Standards' prescriptive packages are higher than those of the most commonly installed window products. This differential between prescriptive requirements and the typical installed products enables using the performance compliance approach to increase the project compliance margin by increasing glass area or, alternatively, to use this built in "window credit" to trade off other efficiency measures and still achieve compliance. Adoption of this CASE proposal would address both of these concerns, enabling the standard energy budget in the performance approach to reflect typically installed residential window products. The revisions proposed here will result in increased envelope efficiency and thus lower the TDV and annual energy use of a typical low-rise residential building. Thus, the extent of potential savings and cost-effectiveness of other, concurrent proposals to update envelope efficiency for the 2013 Standards will be affected by the adoption of this proposal. Vice versa is also true.

3. Methodology

The research supporting this proposal can be divided into four categories: context, market research, building energy simulations, and analysis integrating the above. The research process and methodology as well as its general findings are outlined in this section.

3.1 Context

3.1.1 2008 Title 24

The core of this CASE report addresses the prescriptive fenestration requirements found in Standards Table 151-C, also referred to as prescriptive Package D. The 2008 Package D prescriptive performance requirements for fenestration, which served as the baseline for calculating energy savings, are as follows:

- Maximum U-factor, all climate zones: 0.40
- Maximum Solar Heat Gain Coefficient (SHGC): 0.40, with the following exceptions:
  - 0.35 in climate zone 15
  - No Requirement (NR) in climate zones 1, 3, and 16

Per requirements outlined in the 2008 Residential ACM Manual, software approved for use in performance compliance establishes a Standard Design as the reference for calculating the energy budget for a proposed building. In climate zones where maximum U-factor and SHGC prescriptive requirements are defined, the Standard Design uses them directly. In those with no maximum SHGC requirement, compliance software uses a pre-set SHGC value in the Standard Design.

During analysis for this report, our team discovered an error in this pre-set SHGC value of 0.65 used in the 2008 performance compliance software. Practically speaking, it is not realistic for a double pane low-e window with a U-factor of 0.40 to have an SHGC higher than 0.55. Therefore, for this CASE analysis we corrected this error and instead used a Standard Design SHGC of 0.55 where applicable (climate zones where max prescriptive SHGC = 'NR') in the baseline case simulations. This adjustment better reflects performance of a market-available high solar gain, low-e window and thus provides more representative estimates of savings resulting from the proposed revisions.

3.1.2 Relevant National Efficiency Standards

Nationally recognized codes and criteria that establish levels of fenestration energy efficiency were identified and reviewed, for comparison to the existing California 2008 Standards and to document movement on a national level towards more efficient windows. We sought such relevant national standards also to inform the extent of performance requirements that would be proposed through this CASE report. Details of the relevant national standards are provided in Section 4.1.

3.2 Data Collection

To supplement the contextual information as well as our team's existing knowledge of the industry and market, research was carried out through the following channels.

Window industry surveys. Window product manufacturer and dealer contacts were identified via a combination of channels, including *Window and Door* Top 100 Manufacturers of 2010, CASE stakeholder lists, and industry contacts familiar to the research team. Distinct market surveys were developed for both manufacturers and dealer representatives. Effort was made to collect information from such industry contacts across company size, window frame type, and California's varied climates. Identified persons were contacted via email and/or phone to introduce the goals of the CASE research and to solicit input regarding their company's available products, performance, and costs as well as the current California market as a whole. If receptive to participating, industry contacts were emailed a link to the online survey, estimated to take 15 – 20 minutes to complete. This manufacturer and dealer/distributor survey link is provided in the Appendix, Section 7.1.1. Names of specific company and representative contacted and participating are not included in this report due to agreed upon confidentiality.

Retail site visits. The research team visited a sample of retail home improvement stores and window showrooms in late 2010 and early 2011. Specific locations are identified in the Appendix, Section 7.3.1. These visits informed research questions relating to window type and performance availability, complemented data collected in the industry and energy consultant surveys, and supported determination of appropriate code change proposals and the corresponding incremental costs of achieving them. Recorded variables collected included window size, frame material, operator type, glass type (e.g. low-e, clear), U-factor, SHGC, certifications/rating (e.g., Energy Star), manufacturer, and cost.

Energy consultant interviews. Phone interviews were conducted in March, 2011, with energy consultant contacts/companies serving large-volume home builders in California. Effort was made to include consultants working in a variety of California locations / climate zones. Nine energy consultant contacts/companies that work with production builders were identified and contacted for data on typical window specifications. Seven of these provided input by phone regarding typical window types and performance ranges being installed by their clients. The CASE team focused on consultants serving larger volume builders rather than those of custom or one-off homes, as they would likely better represent 'typical' California market-rate residential construction as well as a larger percentage of constructed homes. A list of contacted consultants is included in Section 7.3.2.

Building department survey. The IOU Codes and Standards team led by HMG coordinated a one-time survey of receptive California building department officials, including questions from across the range of code change proposal topics. A handful of questions relevant to residential fenestration compliance patterns were included by the authors of this report in order to better understand the typical compliance path relevant to windows.

Stakeholder outreach. Stakeholder outreach and requests for input were made at official CASE stakeholder meetings organized by the IOU team in April 2010 and April 2011. The proposed code changes and request for industry input also occurred through the author's presentation at the American Architectural Manufacturers Association (AAMA) 2010 Western Region Spring Meeting, May 5 – 6, 2010. Links to documents and meeting notes from the above activities are provided in the Appendix, Section 7.2.

3.3 Energy Savings and Cost-effectiveness

3.3.1 Criteria for evaluating cost-effective solution

Energy simulation analysis was utilized to evaluate various potential proposals for revising fenestration performance requirements within the context of the following parameters/goals:

- **High statewide TDV savings.** The concept of Total Daily Valuation (TDV) was incorporated into the Standards in 2005 as means to appropriately assign value to energy savings based on the time of day and year it was saved, as well as its source (electricity or natural gas). As a metric TDV addresses the important issue of peak demand in California and serves to encourage and reward measures that save energy when it is most valuable on a statewide basis. For these reasons, TDV savings relative to the 2008 Standards was a key parameter in our analysis.
- **Low Life Cycle Cost (LCC).** Consultants to the CEC developed economic metrics and methodology used across the proposed CASE topics to estimate value, in present dollars, of calculated annual TDV savings resulting from proposed changes to the 2008 Standards. The variables considered, their process, and the resulting methodology are documented in their report for the CEC entitled *Life-Cycle Cost Methodology* (Architectural Energy Corporation, 2010).

  This methodology and its factor for converting estimated annual TDV savings to 30-year present value $ savings was used to calculate the LCC of this report's proposed Standards revisions in each climate zone. Resulting LCC values below zero are cost effective. The greater the negative LCC magnitude, the greater the net savings in present dollars (or net present value, NPV) over the evaluated 30-year period.
- **Minimized impact on heating TDV increases.** The primary energy performance variables for windows are U-factor, which identifies its insulating value and its solar heat gain coefficient (SHGC) which signifies the level of incident solar radiation it prevents from entering a conditioned space. Both values are important in California climates, but SHGC has more direct impact on peak demand reduction in California's cooling climates. Lower SHGC's provide higher cooling TDV savings in hotter climates due to reducing the air conditioning loads that are a significant percentage of California's peak period electricity demand on warm days.

  However, low SHGC values also increase heating equipment loads and TDV, blocking wintertime solar radiation that would otherwise provide passive heating to conditioned space. Thus this CASE report's recommendations necessitated, as does window performance selection in general, balancing the TDV benefits of cooling demand savings with the heating TDV penalty in milder climates.

- **Consistency of proposed requirements across climate zones.** To optimize theoretical potential savings one could recommend fenestration performance requirement packages specific to each climate zone. However, such an approach would not be consistent or practical with the nature of California's window product manufacturing and supply channels. Therefore this report seeks, within the context of the above goals, to recommend a small, feasible number of Package D U-factor/SHGC performance requirement package variations.
- **Achievable performance requirements across the range of typical window types.** The authors recognize that fenestration operator and use types vary in their achievable energy performance. This CASE report seeks to propose requirements that can be met across the range of typical windows installed in California residential buildings.

3.3.2 Building Prototypes and Simulation Parameters

Figure 5, below, describes the prototype buildings used in building energy simulations for this CASE report.

Prototype Building Occupancy Type (Residential, Retail, Office, etc)	Area (Square Feet)	Number of Stories	Other Notes
Residential, Single-Family	2,700	2	Per 2008 Per Section 4.2 of Residential ACM Prototype D (see Bibliography, Section 6.1)
Residential, Multi-Family	6,960	2	8 units. Per Section 4.2 of 2008 Residential ACM Prototype E (see Bibliography, Section 6.1)

Figure 5: Summary Description of Simulated Prototype Buildings

The greatest impact of the proposed revisions would be reducing fenestration U-factor and SHGC requirements for Standards' prescriptive Package D. To evaluate various U-factor and SHGC requirements and their energy impact by climate zone, the following approach was taken using the updated CALRES / MP2013 compliance software modeling tool.

1. Simulate the single-family prototype home in each climate zone for the following cases:
    a. Meeting 2008 Package D in each of the16 climate zones
    b. Incorporating various potential 2013 U-factor and SHGC performance cases (see Figure 6, below) in place of 2008 Package D requirements for all ACM prototype building vertical fenestration.

Case	Description	Performance
PKGD	2008 Package D	U=0.40 / Package D
CLEAR	Dual Glazed Clear	U=0.49 / SHGC=0.65
HSLE	High Solar Low-E	U=0.32 / SHGC=0.50
MSLE	Mid Solar Low-E	U=0.32 / SHGC=0.35
LSLE	Low Solar Low-E	U=0.32 / SHGC=0.30
ELSLE	Extra Low Solar Low-E	U=0.32 / SHGC=0.25
TAX	Tax Credit	U=0.30 / SHGC=0.25
TRIPLE	Triple MSLE	U=0.25 / SHGC=0.28

Figure 6: Summary of Evaluated Window Performance Packages

2. Analyze simulation results across all climate zones and the range of potential fenestration performance value cases using the following metrics per prototype home:
   a. TDV energy savings
   b. Life cycle cost (LCC) / net present value (NPV)
3. Filter the quantitative simulation results through the qualitative parameters/goals as described above in order to establish recommended U-factor and SHGC prescriptive requirements.

   In addition to evaluating the performance package cases shown in Figure 6, potential statewide proposal combinations varying window performance packages by climate zone were also evaluated.
4. Simulate the multi-family prototype using the proposed prescriptive requirements developed in the previous step. Quantify savings statewide and by climate zone, confirming cost-effectiveness of the proposed fenestration requirements for this building type.
5. Present TDV savings and corresponding peak demand (kW) and annual energy (kWh, therm) and savings for each prototype building resulting from the proposed requirements.

   The CALRES 2013 software calculates peak demand internally. Simulated demand for the prototype building during the 250 most demand-constrained hours (statewide) of the year, determined by the 2013 TDV development process and aligned with the 2013 revised weather data, are multiplied by TDV-weighted factors over those 250 hours. The result is the peak demand for that simulated case which, as for annual kwh and therm totals, is then compared to baseline ('standard') case results in order to calculate estimated savings.

4. Analysis and Results

4.1 Relevant National Standards

Nationally recognized codes and criteria that establish levels of fenestration energy efficiency were identified and reviewed for comparison to the existing California 2008 Standards. Provisions in the most recently adopted International Energy Conservation Code (IECC 2012), the U.S. Department of Energy (DOE) and Environmental Protection Agency's (EPA) Energy Star program, and the U.S. federal tax credit criteria were especially relevant. Figure 7 below summarizes the range of recent fenestration standards, across these three national codes/programs and the various California climates. These performance standards, their ranges, and the specific California regions to which each applies are described in the following subsections.

	Energy Star	IECC (2012)	Federal Tax Credit	
			2009 - 2010	2011
U-factor (range)	0.32 - 0.40	0.32 - 0.40	0.30	(same as Energy Star)
SHGC (range)	0.30 - 0.40	0.25 - 0.40	0.30	(same as Energy Star)

Figure 7: Summary of Relevant National Fenestration Performance Standards

4.1.1 Energy Star

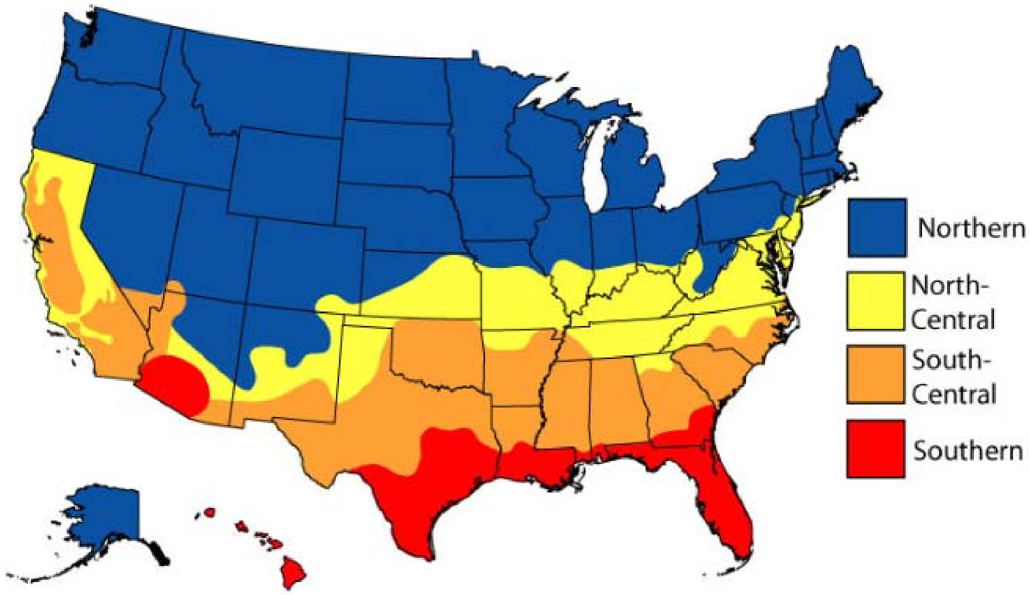


Figure 8: ENERGY STAR Climate Zone Map

North Central region: U-factor = 0.32, SHGC = 0.40
South Central region: U-factor = 0.35, SHGC = 0.30

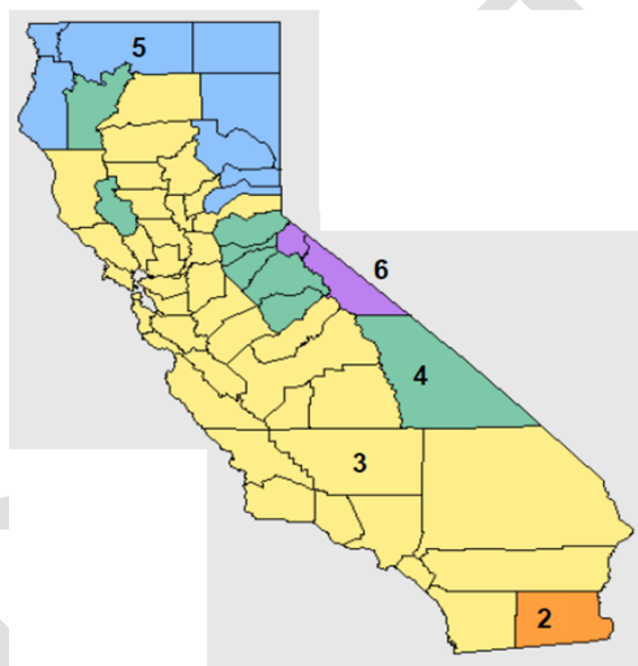
Energy Star is a federal rating/certification program, jointly run by the U.S. Department of Energy (DOE) and the Environmental Protection Agency (EPA). Its primary function is to identify energy efficient options for consumers. The Energy Star label is well established and recognized across a range of product categories, including windows. Due to the national nature of the Energy Star program, in effect it sets a minimum standard for 'high efficiency' windows.

Figure 8, above, portrays the Energy Star climates and the performance criteria required by climate zone for a window product to be Energy Star-labeled. Note that the relevant climate regions to California, North and South-Central, require U-factor and SHGC levels lower than those in the 2008 Title 24 Standards. In other words, nationally the window industry already has a more stringent performance threshold to meet than that required in California.

4.1.2 The International Energy Conservation Code (IECC)

The IECC is a 'model energy code' first released in 1998. It contains minimum energy efficiency provisions for residential and commercial buildings, offering both prescriptive and performance-based approaches, as well as envelope requirements for thermal performance and air leakage. The IECC was initially developed and continues to evolve through public hearings involving national experts and coordinated by the International Code Council (ICC), as part of its family of codes including the International Building Code (IBC), International Residential Code (IRC), and others. It is readily adoptable by a state or local jurisdictions as its main energy code, or can be used as a base upon which to tailor a code to local priorities.

Recently finalized updates to the IECC's 2012 release established the minimum window performance requirements by IECC climate zone shown in Figure 9, below. U-factors are set at 0.32 in cooler California climates. In hotter regions, including those containing most of California's population, SHGC performance levels are 0.25. Similar to but even more so than with the Energy Star label performance criteria, these IECC fenestration standards are more stringent than those of the 2008 Title 24 Standards.



	IECC Climate Zone				
	2	3	4	5, Marine 4	6
U-factor	0.40	0.35	0.35	0.32	0.32
SHGC	0.25	0.25	0.40	NR	NR

Figure 9: IECC Climate Zone Map and Minimum Window Performance Requirements (2012)

4.1.3 Federal Tax Credits

The American Recovery and Reinvestment Act of 2009 (ARRA) provided for energy incentives in the form of tax credits up to $1,500 for both individuals and businesses. Among these was a potential credit for new windows meeting or exceeding the following minimum performance criteria: U-factor = 0.30; SHGC = 0.30. The Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010 continued federal tax credits for windows into 2011, but at lower financial incentive levels and with qualifying performance criteria equivalent to that of the Energy Star program (see Section 4.1.1, above).

4.2 Data Collection

4.2.1 Surveys and Interviews

Window Industry. Manufacturer representatives were more receptive than those from dealers to providing input relevant to this proposal. Reps from five distinct manufacturers participated in the survey, collectively representing a significant portion of the California residential window market. Only one dealer representative, of the many contacted, responded to our invitation to contribute input via the dealer survey.

Survey feedback included confirmation that no significant technical challenges exist to producing high efficiency products at the levels considered in this proposal (the retail site visit component of our research supported this as well—see Section 4.2.2). Manufacturers already make and sell window products of similar performance. A significant percentage of California sales volume for our respondents at the time of our communication could be driven by the 2009-2010 federal tax credits, as shown in
Figure **10** below and also, again, supported by data collected through our retail site visits.

Window Performance Level	**% of CA sales volume** (estimated)	
	Manufacturers	Dealer
Meeting ENERGY STAR criteria	50 - 95%	90%
Meeting (2009-2010) Federal Tax Credit criteria	35 - 60%	80%
EXCEEDING (2009-2010) Federal Tax Credit criteria	1 - 30%	50%

Figure 10: Survey Respondents' Reported California Sales Volumes by Performance Level

The surveyed representatives also sell products in California *exceeding* federal tax credit criteria to various degrees and including both dual and triple-pane windows with U-factors from 0.20 – 0.29 and SHGC values from 0.13 – 0.25. For the same performance level, the dealer respondent reported U-factors of 0.28 – 0.30 and SHGC values from 0.19 to 0.24, both with dual-pane low-e glass.

Three out of five manufacturer respondents and the dealer provided some level of cost data, but were overall hesitant or unable to share absolute incremental costs for high performance windows. Instead, costs were typically given as a percentage increase over the baseline window named in our survey—one meeting the 2008 Title 24 Standards requirements. Note that this baseline window performance level differs from the one ultimately arrived at through the research as a whole, summarized in the following Section 4.2.3. Thus incremental costs reported through the industry surveys are relative to a baseline nonexistent in the market, making respondent's information on this topic less relevant to our research than as well as not directly comparable to incremental cost data collected through retail site visits. That said, manufacturer respondents reported a wide range of additional incremental cost above baseline (10- 30%) between meeting and exceeding the federal tax credit performance criteria. The dealer respondent, however, reported zero additional incremental cost between windows at these two performance levels.

Finally, survey respondents consistently reported a residential market sales volume skew towards retrofit / renovation over new construction, and towards single-family over multi-family. These findings are shown in Figure 11.

Low-rise Residential Market Sector	**% of CA sales volume** (estimated)	
	Manufacturers	Dealer
New Construction	20 – 50%	30%
Retrofit + Renovation	50 – 80%	70%
Single-Family	60 – 80%	65%
Multi-Family	20 – 40%	35%

Figure 11: Survey Respondents' Reported California Sales Volumes by Residential Market Sector

Energy Consultants. Contacts interviewed confirmed findings through other research channels that the baseline window product installed in California is already better performing than that required by the current 2008 Standards. Low-e glass is the norm, and U-factors / SHGC of 0.35 / 0.35 are basically default values. While not universal, SHGC values in the low to mid-0.20's are common and, for some builders the interviewees work with, already standard practice.

Building Departments. Relative to this topic, California building department staff were asked regarding the frequency of residential compliance via the prescriptive path. The thirty-four responses are tabulated in Figure 12, below.

Approximately, how many residential permits were filed over the past 4 years used the prescriptive method?		
Answer Options	**Response Percent**	**Response Count**
None (0%)	9%	3
Very few (1-10%)	41%	14
Few (11-40%)	24%	8
Many (41-80%)	15%	5
Most (81-100%)	12%	4

Figure 12: Building Department Survey, Frequency of Prescriptive Compliance

The main take-away from Figure 12 is that 74% of respondents estimate few to none of the residential building permits processed at their jurisdiction complied with Title 24 Standards using the prescriptive approach. Looked at another way, this data confirms our hypothesis that the performance method is the predominant compliance path for permitted residential construction. This confirmation supports updating the fenestration prescriptive standards at least to the actual market performance baseline in order to remove the ‘built-in’ window compliance credit. Such credit, which can be traded off against other efficiency measures, results from a market baseline but better-than-code windows being installed as the default and, when compared to the 2008 Package D requirements reflected in the performance approach Standard Design, indicating efficiency ‘savings’ above a non-existent typical window product.

4.2.2 Retail Site Visits

As described in Section 3.2, data collection research included visits to several retail locations to documented in-stock and display windows. All observed windows were dual-pane, and most were low-e glass. The distribution of their U-factor and SHGC performance values are provided in the following figures, Figure 14 and Figure 13, respectively.

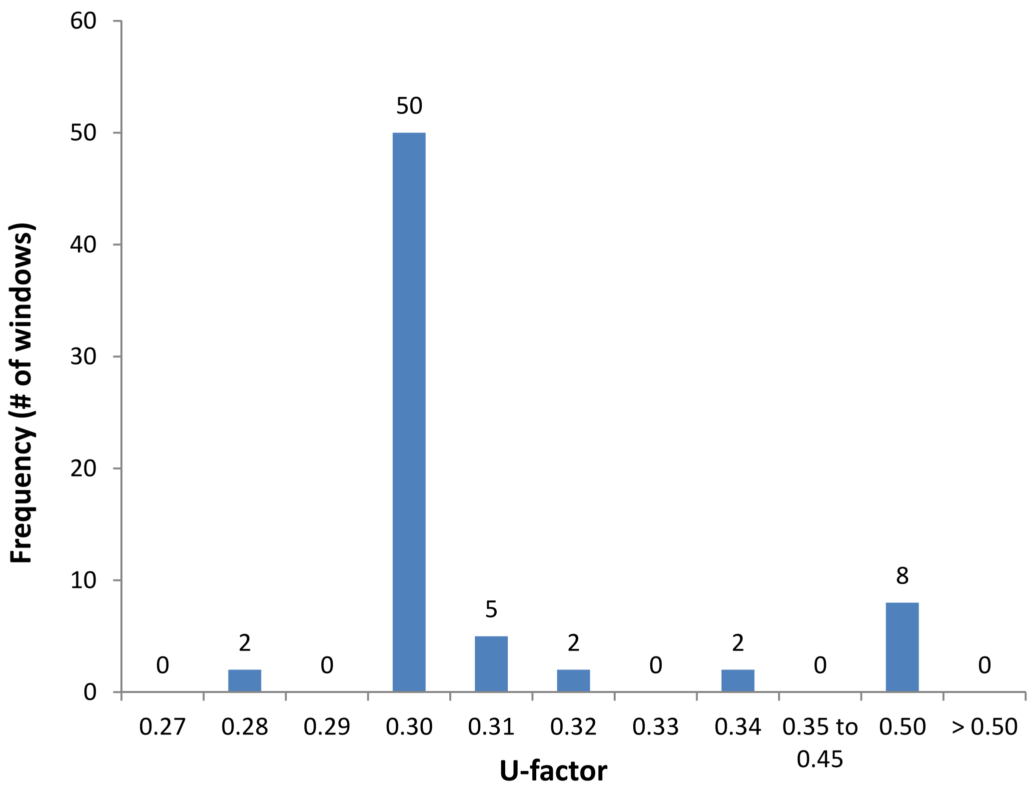


Figure 13: Retail Site Visits, Product Histogram: U-factor

As Figure 13 conveys, most windows (75%) had U-factors at or below 0.32. The eight products with U-factors between 0.45 and 0.50 were clear glass varieties.

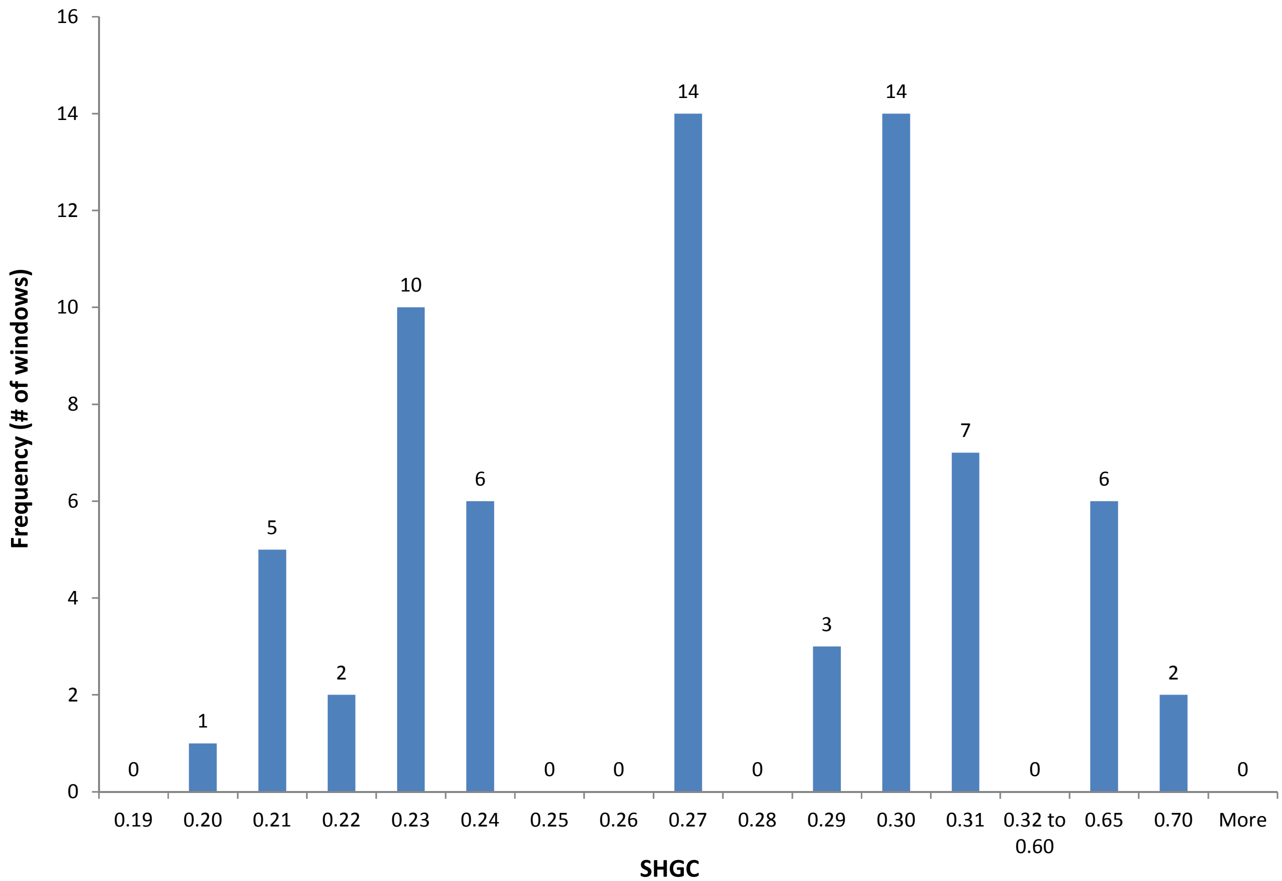


Figure 14: Retail Site Visits, Product Histogram: SHGC

The distribution of SHGC values across observed in-stock retail windows is shown in Figure 14, above. 34% of SHGC performance values were at 0.24 or lower, and 79% were at or below 0.30, similar to the percentage of window U-factors below 0.30. U-factor = 0.30/SHGC = 0.30 are together the minimum qualification levels for the 2010 federal tax credits, which had just ended at the time of our data collection. It is apparent that manufacturers and the retail outlets responded to the tax credit criteria in their production and inventory decisions. Most windows also carried the Energy Star label.

Costs per square foot of window for low-e glass products varied only slightly across the range of U-factors and SHGC values shown in the figures above. In some cases the higher performance window actually cost the same or less than a lower performance window. Overall, collected data shows that incremental costs of production and to end-use consumers due to varying performance levels of low-e windows are small to none. Incremental costs used in our cost-effectiveness analysis are based primarily on these retail site visits and are included in Figure 3 and Figure 4, Section 2(i) of this report.

4.2.3 Overall Findings

Collectively, the research described here documented current typical practice, including defining the baseline window in terms of the energy performance of products being typically sold/installed, confirming the availability of high performance window products, and quantifying an estimated incremental cost (relative to the existing baseline) to meet the proposed prescriptive requirements. The over-arching findings across research channels are summarized below. These findings informed the energy and cost-effectiveness analysis described in the next section as well as the requirements proposed in this report.

- Window products matching the prescriptive efficiency requirements of the 2008 Standards, Table 151-C (Package D), are difficult to find if not non-existent in the market. Even the lesser performance low-e windows installed and available for purchase typically exceed the efficiencies required by 2008 Package D.
- The 'market baseline' window, and that on which incremental costs outlined in Section 2(i) and described in Section 4 of this report are based, can be described as follows:
    - Installed type/characteristics: vinyl frame, double-pane air or argon-filled, low-e glass
    - Available/installed performance levels – U-factor: 0.30 – 0.35, SHGC: 0.23 – 0.35
    - Incremental costs: minimal across above typical performance levels

4.3 Energy Simulation Analysis

4.3.1 Analysis Setup

Initially the range of window specifications defined in Figure 6 were modeled individually across the climate zones. Based on review of results from each of these runs, a number of "straw proposals" were developed for impacts analysis for the prototype single-family home on a statewide basis. Three such proposals are presented in Figure 15, below, developed by the CASE team per parameters described in the Section 3.3.1.

In addition to optimizing savings and NPV, effort was made to minimize the number of distinct U-factor/SHGC packages. The number of such packages varies between two and three per statewide straw proposal (including ELSLE, LSLE, and HSLE as defined previously in Figure 6).

<table>
<tr><th rowspan="2">Climate Zone</th><th colspan="4">Window Performance Package</th><th rowspan="2">Climate Zone</th></tr>
<tr><th>Straw 1</th><th>Straw 2</th><th>Straw 2A</th><th>Straw 3</th></tr>
<tr><td>01</td><td>HSLE</td><td>HSLE</td><td>HSLE</td><td>HSLE</td><td>01</td></tr>
<tr><td>02</td><td>ELSLE</td><td>ELSLE</td><td>ELSLE</td><td>LSLE</td><td>02</td></tr>
<tr><td>03</td><td>HSLE</td><td>HSLE</td><td>HSLE</td><td>HSLE</td><td>03</td></tr>
<tr><td>04</td><td rowspan="12">ELSLE</td><td>ELSLE</td><td>ELSLE</td><td>LSLE</td><td>04</td></tr>
<tr><td>05</td><td>HSLE</td><td>HSLE</td><td>HSLE</td><td>05</td></tr>
<tr><td>06</td><td rowspan="11">ELSLE</td><td rowspan="10">ELSLE</td><td rowspan="3">LSLE</td><td>06</td></tr>
<tr><td>07</td><td>07</td></tr>
<tr><td>08</td><td>08</td></tr>
<tr><td>09</td><td rowspan="7">ELSLE</td><td>09</td></tr>
<tr><td>10</td><td>10</td></tr>
<tr><td>11</td><td>11</td></tr>
<tr><td>12</td><td>12</td></tr>
<tr><td>13</td><td>13</td></tr>
<tr><td>14</td><td>14</td></tr>
<tr><td>15</td><td>15</td></tr>
<tr><td>16</td><td>HSLE</td><td>HSLE</td><td>LSLE</td><td>16</td></tr>
</table>

Figure 15: Primary "Straw Proposals" Evaluated

4.3.2 Results

Statewide TDV savings averages and the corresponding LCC for the single family prototype, weighted by percentage of construction starts by climate zone, were compared across straw proposals. Among the evaluation criteria were high statewide TDV savings, low 30-year LCC, and positive heating TDV impacts in mild climates, as discussed in Section 3.3 in greater detail. Attention was paid to achieving these goals in each climate zone as well as on a statewide basis.

Evaluated Proposal	Total TDV savings		PV Savings	Cost	NPV
	kTDV/ft2	%	$	$	$
Straw 1	9.8	13.7%	$4,571	($383)	$4,188
Straw 2	10.0	14.1%	$4,690	($383)	$4,307
Straw 2A	9.9	14.0%	$4,622	($383)	$4,239
Straw 3	9.3	12.7%	$4,369	($226)	$4,144

Figure 16 summarizes analysis results from straw proposals 1, 2, 2A, and 3. All show significant statewide TDV savings and NPV savings, therefore all are cost-effective. Straw 2 demonstrates the strongest results in these categories, especially compared to Straw 3, as well as achieving positive

NPV in all climate zones (as opposed to Straw 1). Straw 2A, different only in the window performance package for climate zone 16, falls just short of Straw 2 in both estimated savings and NPV.

Evaluated Proposal	Total TDV savings		PV Savings	Cost	NPV
	kTDV/ft2	%	$	$	$
Straw 1	9.8	13.7%	$4,571	($383)	$4,188
Straw 2	10.0	14.1%	$4,690	($383)	$4,307
Straw 2A	9.9	14.0%	$4,622	($383)	$4,239
Straw 3	9.3	12.7%	$4,369	($226)	$4,144

Figure 16: Summary Comparison of Straw Proposal Simulation Statewide Results

4.4 Conclusions and Recommendations – New Construction

Straw 2's window performance package / climate zone combinations described in Figure 17 are recommended as 2013 Package D fenestration performance requirements. This package of requirements most successfully meets the multiple goals for the CASE as described in Section 3.3.1.

	Description
Standard	U-factor 0.40 SHGC per Package D* (no overhang)
Proposed (Straw 2)	ELSLE in CZ 2, 4, 6-16: U-factor 0.32, SHGC 0.25 HSLE in CZ 1, 3, 5: U-factor 0.32, SHGC 0.50

Figure 17: Standard and Proposed Fenestration Cases

The 2008 Standards Package D served as the modeled standard design for calculating potential energy savings. SHGC was adjusted to 0.55 for the 'Standard' case in climate zones where no maximum SHGC is currently required, as described previously in Section 3.1.1.

Negative life cycle costs (LCC) resulted from the proposed requirements in all climate zones. Thus the proposed revisions are demonstrated to be cost-effective. Simulated energy saving and cost-effectiveness results for the proposed requirements for single and multi-family new construction prototype buildings across California's sixteen climate zones are further discussed in the following subsections, and summarized in Overview Section 2(i). Corresponding proposed code language is presented in Section 5 below.

4.4.1 Savings and Cost-effectiveness: Single-Family

Comparison of the single-family prototype simulation results for the 'standard' and 'proposed' cases described in Figure 17 (above), including TDV savings and cost-effectiveness, are summarized in Figure 18, below. In this figure positive $ numbers indicate savings.

Climate Zone	Proposed Design Window Spec	Difference (Proposed - Standard)			Percent Difference (Proposed - Standard / Standard)			Net Present Value		
		Heating kTDV/ft2	Cooling kTDV/ft2	Total kTDV/ft2	Heating	Cooling	Total	Savings $	Cost $	NPV $
01	HSLE	-2.6	0.0	-2.6	-8%	0%	-5%	$1,216	($383)	$832
02	ELSLE	1.4	-5.9	-4.5	5%	-47%	-8%	$2,090	($383)	$1,707
03	HSLE	-1.4	-0.7	-2.1	-8%	-16%	-5%	$982	($383)	$599
04	ELSLE	1.6	-9.4	-7.8	8%	-46%	-13%	$3,624	($383)	$3,241
05	HSLE	-5.8	0.4	-5.4	-28%	0%	-14%	$2,525	($383)	$2,142
06	ELSLE	1.5	-8.3	-6.8	19%	-45%	-16%	$3,184	($383)	$2,801
07	ELSLE	1.0	-6.3	-5.3	46%	-42%	-16%	$2,488	($383)	$2,104
08	ELSLE	1.1	-10.0	-8.9	19%	-32%	-17%	$4,162	($383)	$3,778
09	ELSLE	1.2	-12.9	-11.8	13%	-25%	-15%	$5,494	($383)	$5,111
10	ELSLE	1.3	-13.9	-12.7	13%	-25%	-15%	$5,920	($383)	$5,537
11	ELSLE	1.0	-18.9	-17.9	5%	-22%	-14%	$8,380	($383)	$7,996
12	ELSLE	0.8	-13.4	-12.6	4%	-28%	-14%	$5,887	($383)	$5,504
13	ELSLE	0.5	-19.1	-18.6	3%	-22%	-15%	$8,698	($383)	$8,314
14	ELSLE	1.9	-15.3	-13.5	9%	-20%	-12%	$6,294	($383)	$5,911
15	ELSLE	0.0	-14.1	-14.1	-2%	-10%	-9%	$6,607	($383)	$6,224
16	ELSLE	6.7	-20.5	-13.9	15%	-65%	-15%	$6,486	($383)	$6,102
Statewide		**0.9**	**-11.0**	**-10.0**	**12%**	**n/a**	**-14.1%**	**$4,690**	**($383)**	**$4,307**
Average		0.6	-10.5	-9.9	7%	-32%	-13%	$4,627	($383)	$4,244
Min		-5.8	-20.5	-18.6	-28%	-65%	-17%	$982	($383)	$599
Max		6.7	0.4	-2.1	46%	-10%	-5%	$8,698	($383)	$8,314

Figure 18: Comparison of Proposed and Standard Simulation Results, Single Family Prototype D

The prototype home incorporating the proposed revisions (Figure 18 'Proposed' case) results in simulated TDV savings ranging from 2.1 to 18.6 kTDV/sf (5 - 17%) relative to the same home built per 2008 Package D (Figure 18 'Standard' case). Factoring in weighted new construction starts by climate zone, this translates to 10.0 kTDV/sf or 14% statewide TDV savings per prototype single-family home.

Based on incremental costs per square foot of window area summarized in Section 2(i), estimated incremental costs per prototype home was $383. The 30-year NPV of the LCC savings calculated per designated CEC methodology ranged from $599 to $8,314 across California's sixteen climate zones (see Figure 18, above). Cost-effectiveness of the proposed prescriptive requirement revisions by climate zone is summarized in Section 2(i) of this report.

4.4.2 Savings and Cost-effectiveness: Multi-Family

Comparison of the low-rise multi-family prototype simulation results for the 'standard' and 'proposed' cases described in Figure 17 (above), including TDV savings and cost-effectiveness, are summarized in Figure 19, below. In this figure positive $ numbers indicate savings, not costs.

	Proposed Design	Difference (Proposed - Standard)			Percent Difference (Proposed - Standard / Standard)			Net Present Value		
Climate Zone	Window Spec	Heating kTDV/ft2	Cooling kTDV/ft2	Total kTDV/ft2	Heating	Cooling	Total	Savings $	Cost $	NPV $
01	HSLE	-1.8	0.0	-1.8	-11%	0%	-3%	$2,170	($741)	$1,428
02	ELSLE	0.6	-5.9	-5.4	4%	-34%	-8%	$6,461	($741)	$5,720
03	HSLE	-1.0	-0.6	-1.6	-13%	-9%	-3%	$1,880	($741)	$1,139
04	ELSLE	0.6	-7.9	-7.3	7%	-28%	-10%	$8,751	($741)	$8,010
05	HSLE	-3.0	1.7	-1.3	-37%	271%	-3%	$1,507	($741)	$765
06	ELSLE	0.3	-6.9	-6.6	20%	-25%	-11%	$7,980	($741)	$7,238
07	ELSLE	0.0	-5.9	-5.8	100%	-26%	-10%	$7,039	($741)	$6,298
08	ELSLE	0.2	-7.4	-7.3	16%	-19%	-10%	$8,739	($741)	$7,998
09	ELSLE	0.3	-9.4	-9.1	14%	-15%	-9%	$10,921	($741)	$10,180
10	ELSLE	0.4	-9.6	-9.2	14%	-16%	-9%	$11,065	($741)	$10,324
11	ELSLE	0.2	-11.5	-11.3	2%	-13%	-9%	$13,609	($741)	$12,868
12	ELSLE	0.1	-9.7	-9.6	1%	-18%	-10%	$11,608	($741)	$10,867
13	ELSLE	0.0	-11.1	-11.1	0%	-13%	-9%	$13,428	($741)	$12,687
14	ELSLE	0.9	-10.8	-9.9	9%	-14%	-8%	$11,982	($741)	$11,240
15	ELSLE	0.0	-9.7	-9.7	0%	-7%	-5%	$11,644	($741)	$10,903
16	ELSLE	3.7	-16.7	-13.0	13%	-48%	-13%	$15,622	($741)	$14,881
Statewide		**0.2**	**-8.0**	**-7.8**	**n/a**	**n/a**	**-9.1%**	**$9,427**	**($741)**	**$8,686**
Average		0.1	-7.6	-7.5	9%	-1%	-8%	$9,025	($741)	$8,284
Min		-3.0	-16.7	-13.0	-37%	-48%	-13%	$1,507	($741)	$765
Max		3.7	1.7	-1.3	100%	271%	-3%	$15,622	($741)	$14,881

Figure 19: Comparison of Proposed and Standard Simulation Results, Multi-Family Prototype E

The prototype multi-family building incorporating the proposed revisions (Figure 19 'Proposed' case) results in simulated TDV savings ranging from 1.3 – 13.0 kTDV/sf (3 - 13%) relative to the same home built per 2008 Package D (Figure 19 'Standard' case). Factoring in weighted new construction starts by climate zone, this translates to 7.8 kTDV/sf or 9% statewide TDV savings per prototype multi-family building.

Based on incremental costs per square foot of window area summarized in Section 2(i), incremental cost per prototype building was $741. The 30-year NPV of the LCC savings calculated per designated CEC methodology ranged from $765 to $14,881 across California's sixteen climate zones (see Figure 19, above). Cost-effectiveness of the proposed prescriptive requirement revisions by climate zone is summarized in Section 2(i) of this report.

4.5 Conclusions and Recommendations – Existing Buildings

This report does not quantify estimated potential savings from the retrofit / renovation window market, which per our collected research (see Figure 11, Section 4.2.1) currently makes up a majority of California residential window sales volume. Collected data presented here regarding window performance and availability would also be applicable to window retrofits in existing buildings. However, due to the varying vintages of existing buildings and the varying nature of their window types, identifying a 'typical' single and multi-family building for analysis is more difficult and less appropriate. Thus quantifying expected savings for fenestration retrofits of existing single or multi-family buildings is less conducive to the simulation-based approach described here.

However, following the reasonable assumption that existing California buildings, including their windows, are less energy efficient than new construction, retrofit / replacement windows would result in a greater potential savings for the same incremental cost. Thus the proposed revisions are deemed cost-effective for the retrofit/replacement market as well.

5. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

This section outlines code language corresponding to the proposed Standards revisions described in this report. Altered values from the 2008 Standards are in ~~blue, crossed-out text~~. Proposed 2013 revisions are in underlined red.

5.1 *Package D*

As described previously, revisions to prescriptive Package D make up the core of this proposal. Figure 20, below, outlines proposed code language changes to Package D.

(Package D)	CLIMATE ZONE															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Maximum U-factor	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**	~~0.40~~ **0.32**
Maximum SHGC	NR	~~0.40~~ **0.25**	NR	~~0.40~~ **0.25**	~~0.40~~ **NR**	~~0.40~~ **0.25**	~~0.40~~ **0.25**	~~0.40~~ **0.25**	~~0.40~~ **0.25**	~~0.40~~ **0.25**	~~0.40~~ **0.25**	~~0.40~~ **0.25**	~~0.40~~ **0.25**	~~0.40~~ **0.25**	~~0.35~~ **0.25**	~~NR~~ **0.25**

Figure 20: Proposed Revisions to Standards Section 151, Table 151-C

Note that Figure 20 lists 'NR' (no requirement) for SHGC in heating-dominated climate zones 1, 3, and 5, rather than the 0.50 value (HSLE window—see Figure 6, Figure 15, and Figure 17) simulated in our straw proposals, including Straw 2 which informs the proposed revisions. Such an approach to implementing code language is consistent with past fenestration updates and familiar to the industry and market. In addition, with low-e / low-solar windows the predominant product type in the California market, the 'NR' designation also eases prescriptive compliance where a low-e / high-solar window (U-factor = 0.32 / SHGC = 0.50) may not be as available for purchase.

The SHGC = 0.50 value would, however, replace the current Standard Design value of 0.65 used to determine the energy budget for performance compliance in climate zones 1, 3, and 5. Builders in these climate zones complying via the performance approach would therefore be rewarded for using low-e / high-solar windows, and conversely need to increase efficiency in other areas to compensate for the energy penalty of using the low-solar gain windows required in all other climate zones.

5.2 *Package C*

Package C allows for prescriptive compliance with electric resistance space and water heating. In return it requires increased envelope efficiency as well as solar water heating to balance the increased TDV that would otherwise result. The intent is that a building built to Package C with electric heating results in equivalent energy impacts in each climate zone as one built per Package D (with natural gas heating).

Because 2013 Package D will be affected by this as well as other proposed code revisions, the 2013 Package D baseline is not yet established. Thus a Package C resulting in equivalent energy usage as

Package D cannot yet be determined. Although proposed revised fenestration performance values for Package C will be equal to or lower than those proposed for Package D, final Package C values resulting in equivalent energy usage, in conjunction with other envelope measures, cannot yet be finalized. Proposed revisions to Package C will be developed and corresponding proposed code language revisions incorporated into Figure 21, below, once 2013 Package D is established.

(Package C)	CLIMATE ZONE															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Maximum U-factor	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)
Maximum SHGC	NR (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.35 (TBD)	NR (TBD)

Figure 21: Proposed Revisions to Standards Section 151, Table 151-B (TBD)

5.3 Package E

Package E, Standards Section 151, Table 151-D, appeared for the first time in the 2008 Standards. It intends to represent equivalent energy usage as Package D while allowing for higher U-factor windows. Package E balances the lower efficiency of such windows with increases in required efficiency of other prescriptive building components in order to achieve equivalent energy impacts as Package D in each climate zone.

With the significant increase in typical window performance reflected in this report's proposed revisions, not to mention Package D changes being proposed by other authors, achieving equivalent energy use through augmenting other envelope features in Package E may be difficult if not infeasible in many climate zones. The authors of this report recommend eliminating Package E as a prescriptive option in the 2013 Standards. The performance approach could instead be selected for compliance in cases where prescriptive Package E had previously been used.

If eliminating Package E is deemed not feasible, then efforts to update it can be made. As with Package C, because 2013 Package D will be affected by this report's as well as other proposed revisions, the 2013 Package D baseline is not yet established and thus a Package E resulting in equivalent energy impacts cannot yet be developed. Should they be necessary, proposed revisions to Package E and the corresponding code language would be developed once 2013 Package D is established.

6. Bibliography and Other Research

6.1 Documents and Resources

2008 Building Energy Efficiency Standards for California (Title 24, Section 6), and accompanying documents (http://www.energy.ca.gov/title24/2008standards/index.html), including the following:

- 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings: http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF
- 2008 Residential Compliance Manual: http://www.energy.ca.gov/2008publications/CEC-400-2008-016/CEC-400-2008-016-CMF-REV1.PDF
- 2008 Residential Alternative Compliance Method (ACM) Approval Manual: http://www.energy.ca.gov/2008publications/CEC-400-2008-002/CEC-400-2008-002-CMF.PDF
- 2008 Reference Appendices: http://www.energy.ca.gov/2008publications/CEC-400-2008-004/CEC-400-2008-004-CMF.PDF

Architectural Energy Corporation. *Life-Cycle Cost Methodology: 2013 California Building Energy Efficiency Standards*. California Energy Commission. November 16, 2011. http://energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/2011-01-14_LCC_Methodology_2013.pdf

D&R International, Ltd. *Windows Doors, and Skylight: Draft Criteria and Analysis*. U.S. Department of Energy ENERGY STAR Program. August 6, 2008.

Energy Star program, main site: http://www.energystar.gov/

Energy Star program, window qualification criteria: http://www.energystar.gov/ia/partners/prod_development/archives/downloads/windows_doors/WindowsDoorsSkylightsProgRequirements7Apr09.pdf

Federal tax credit window criteria: http://www.energystar.gov/index.cfm?c=tax_credits.tx_index

IECC 2012 window requirements: email correspondence to Ryan Schmidt from Ken Nittler, 4/5/2011

7. Appendices

7.1 Survey Instruments

7.1.1 Manufacturer and Dealer Market Survey:

http://www.surveymonkey.com/s/Y8ZXN3S

7.2 Stakeholder Outreach

7.2.1 CASE Residential Envelope Stakeholder meetings

Stakeholder Meeting #1 - San Ramon, CA: April 13, 2010

Agenda: http://www.h-m-g.com/T24/Res_Topics/Res_Envelope_Mtg_1/ResEnvelopeStakeholderMtg1Agenda.pdf

Presentations: http://www.h-m-g.com/T24/Res_Topics/Res_Envelope_Mtg_1/ResEnvelopeStakeholderMtg1Presentations.pdf

Meeting Notes: http://www.h-m-g.com/T24/Res_Topics/Res_Envelope_Mtg_1/Res%20Envelope%20Meeting%201%20Notes.pdf

Stakeholder Meeting #2 - Davis, CA: April 12, 2011

Agenda: http://www.h-m-g.com/T24/Res_Topics/2011.04.12MeetingDocuments/Res_Meeting2_Agenda.pdf

Presentation: http://www.h-m-g.com/T24/Res_Topics/2011.04.12MeetingDocuments/Res_4_2nd_Stakeholder_Mtg_SchmidtNittler_041111.pdf

Meeting Notes: http://www.h-m-g.com/T24/Res_Topics/2011.04.12MeetingDocuments/ResStakeholderMtg2_CondensedNotes_041211.pdf

7.2.2 Conference Presentations

2010 AAMA Western Regional Meeting - Oakland, CA: May 5 -6, 2010
California Code Update

7.3 Data Collection

7.3.1 Retail Sites

Home Depot – Colma, CA: November 30, 2010
Truitt & White window showroom – Berkeley, CA: January 26, 2011
(http://www.truittandwhite.com/win_door/)
Home Depot – Emeryville, CA: January 26, 2011
Lowe's – San Bruno, CA: January 27, 2011
Home Depot – Colma, CA: January 27, 2011
Home Depot Pro – Colma, CA: January 27, 2011

7.3.2 Survey Contacts

Energy Consultant, Company. Contact Date
Bob Seibel, Consol. March 11, 2011
Rudy Sains, Heritage Energy Group. March 11, 2011
Rick Maurer, Rick Maurer Title-24. March 11, 2011
Mark Gallant, Gallant Energy Consulting. March 11, 2011
Jeremiah Ellis Duct Testers. March 11, 2011
Bill Lilly, California Living. March 11, 2011
Bill Mattinson, SolData. March 11, 2011
Marcos Hernandez, Beutler. March 11, 2011